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Engineer Site Identification for the Tactical Environment (ENSITE)

Development of Analytical Plug-Ins for ENSITE

Version 1.0

Matthew D. Hiett, Natalie R. Myers, George W. Calfas, Elizabeth G. Bastian, Kathryn O. Fay, Noah W. Garfinkle, Ellen R. Hartman, Ryan W. Keeling, Eric L. Kreiger, Kate A. Morozova, Juliana M. Wilhoit, and Danielle M. Williams

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Construction Engineering Research Laboratory

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Final report

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Abstract

To sustain itself as the world's premier land power, the U.S. Army needs the capability to support expeditionary forces by projecting a minimal basing footprint with reduced logistical burdens. Strategically sited contingency bases (CBs) allow the Army's expeditionary forces to rapidly respond throughout a joint area of operations. To help with this goal, the Army is funding work in the Engineer Site Identification for the Tactical Environment (ENSITE) program, which is dedicated to empowering military planners with the data and knowledge to site CB locations. ENSITE's core-software platform builds upon leading geospatial platforms already in use by the Army and is designed to offer an easy-to-use, customized set of workflows for CB planners. Within this platform are added software components (plug-ins) that add specific and powerful functionality and features for analyses, while minimizing the program's complexity to the end user. This report provides a snapshot of the ENSITE plug-in development process. Completed midway in the four-year ENSITE research effort, this report provides an overview of the initial process of developing 10 plug-ins and reflects on the way forward for the plug-in development process.

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Preface

This work was conducted for the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA(ALT)) under applied research program T45, Project 45509, “Contingency Base Site Evaluations for Tactical Environment.” The technical monitor was Mr. Kurt Kinnevan, CEERD-CZT.

The work was performed by the Environmental Processes Branch (CNE) of the Installations Division (CN), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Mr. Garth Anderson was Chief, CEERD-CNE; Mr. Donald K. Hicks was Acting Chief, CEERD-CN; and Mr. Kurt Kinnevan, CEERD-CZT, was the Technical Director for Adaptive and Resilient Installations. The Interim Deputy Director of ERDC-CERL was Ms. Michelle J. Hanson, and the Interim Director was Dr. Kirankumar V. Topudurti.

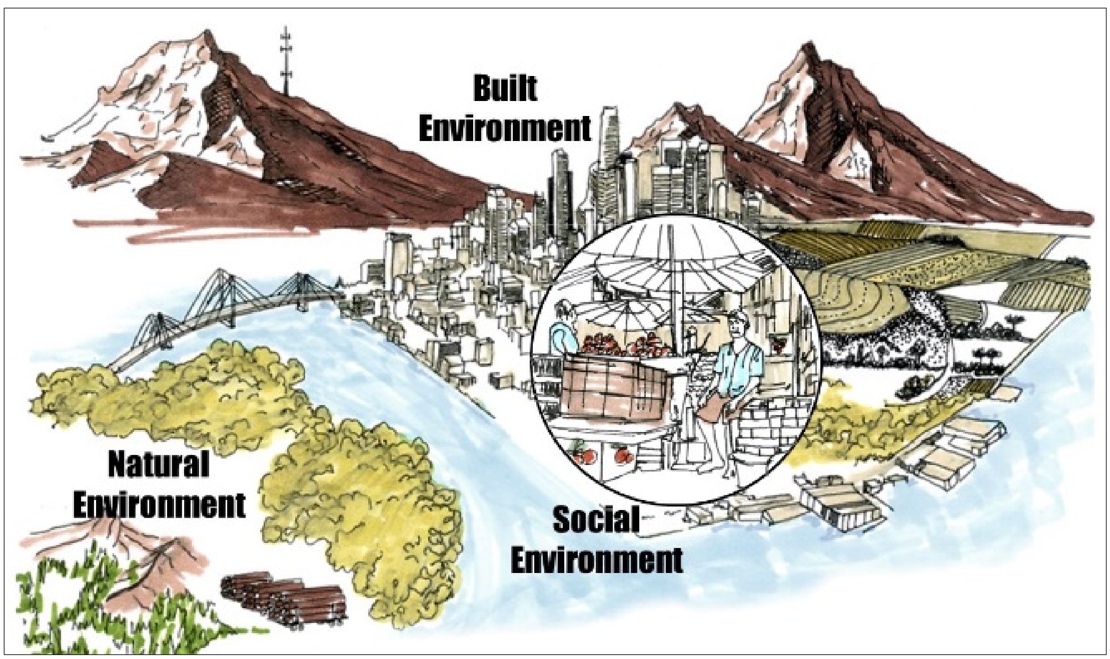
The Commander of ERDC was COL Bryan S. Green, and the Director was Dr. David W. Pittman.

1 Introduction

1.1 Background

The Engineer Site Identification for the Tactical Environment (ENSITE) program is dedicated to empowering military planners with the data and knowledge for choosing the best contingency base (CB) locations. The program is sponsored by the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA(ALT)), with a funding timeline from October 2015 through September 2018. Figure 1 illustrates that the problems addressed by ENSITE research program are interrelated, and they come together in the place where the built environment, natural environment, and sociocultural environment intersect. These problems could impact CB site decisions.

Figure 1. ENSITE program overview.



Base camp locations and designs are not one-size-fits all; rather they should be viewed as a multilayer decision process that supports the Army's mission and the commander's intent. The built, ecological, and sociocultural environments impact military bases and, in turn, military bases affect those three environments. Failure to understand these mutual effects may

result in increased logistical burdens for the Army and unintended consequences for local populations and natural resources. These results can then negatively impact the military mission.

ENSITE provides military planners with the ability to integrate and visualize data about the built, natural (ecological), and sociocultural environments—data that will support analysis of CB site selection. ENSITE is an analysis software that builds upon leading geospatial platforms already in use by the Army (including ESRI ArcMap®) and offers an easy-to-use, customized set of workflows that will remotely evaluate the built, natural, and sociocultural characteristics of a potential CB location. With such a tool, planners (as well as designers, operators, and managers) can rapidly assess current and future situations to provide proactive operational control and alternative situational analyses while they are either deployed or in training.

ENSITE's software capabilities support the full life cycle of the base—from design, construction, and operations/management, to deconstruction. ENSITE features software components that add specific functions and features while minimizing complexity for the end user. This flexibility and ease of operation allows users to deploy ENSITE in the field. ENSITE combines Army doctrine, open-source data, and authoritative Army data in conjunction with user input to execute automated processes capable of processing large amounts of environmental data in a rapid, consistent, and standardized manner.

Beyond its core software, ENSITE is constructed as a collection of software components (commonly referred to as "plug-ins") that support analysis of a CB site by providing answers to the following questions:

- What resources and infrastructure are locally available?
- Are military operations likely to affect the life patterns of the local population?
- Where will the construction of a base camp best leverage local resources and minimize local sociocultural or environmental impacts?
- How can a base camp be built for both a specific intent and a sustainable life cycle?

1.2 Objective

This report is to serve as a snapshot of the ENSITE plug-in development process by describing the general approach for how initial plug-ins were developed and integrated within ENSITE's core software.

1.3 Approach

Within this report, Chapter 2 provides an overview of the plug-in development process including the roles and responsibilities of key players. It introduces the workflow chart that depicts the sequence of procedural steps to be followed. Chapter 3 details the required contents within each step. Chapter 4 concludes by highlighting the results of this process and reflecting on the way forward, providing helpful plug-in examples, and commenting on future improvements.

1.4 Scope

This report is noted as version 1.0 because it was completed mid-development during the four-year ENSITE research effort. Updated versions are anticipated as the Army's needs and the ENSITE program evolve. ENSITE's has 10 analytical plug-in capabilities as of the time of this publication, which are listed in Section 4.1 of this report.

2 Plug-in Basics

2.1 What is a plug-in?

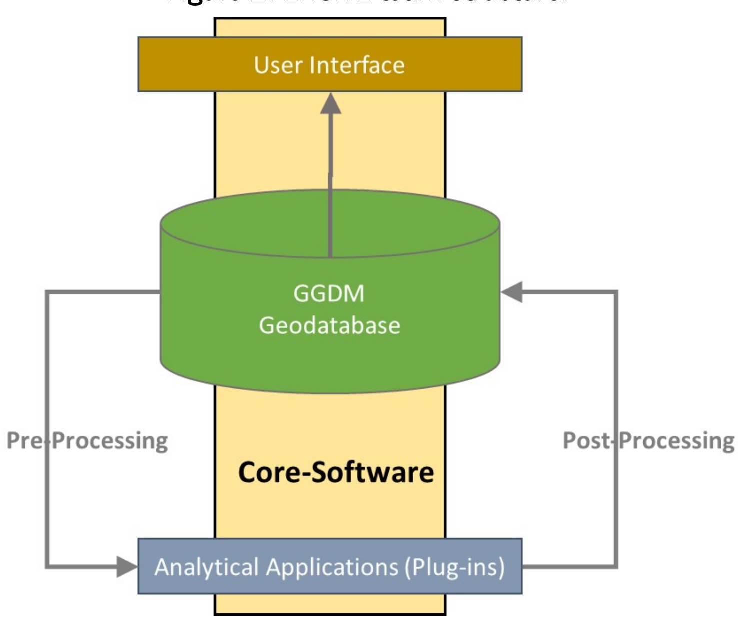
Plug-in applications (plug-ins) are discrete packages of code that extend the core functionality of ENSITE's software. Plug-ins provide the ability to create custom software capabilities without investing the large number of resources necessary to build an additional software platform from the ground up. Plug-ins allow ENSITE to remain flexible in its offered capabilities by offering quick response to the needs of a user community.

ENSITE plug-ins can be as simple or as complicated as necessary. Current capabilities range from calculating slope from elevation data to identifying areas from which a CB is vulnerable from direct enemy fire.

2.2 Key players in development

The overall ENSITE program is divided into three primary subteams—the Analysis team, Data team, and Core-Software team. Each team has distinct roles and responsibilities (see list that follows), and a plug-in developer must interact with members of each team. Figure 2 illustrates this subteam structure.

Figure 2. ENSITE team structure.



2.2.1 Plug-in developer

The plug-in's developer is a member of the Analysis Team. He or she is the primary point of contact (POC) for a specific plug-in and is ultimately responsible for producing the plug-in to match the requirements of ENSITE. He or she also executes the workflow process, as described in Section 2.3.

2.2.2 Analysis Team

The Analysis Team is composed of plug-in developers, ENSITE stakeholders, and a documentation coordinator. Team members are responsible for coordinating and producing plug-in applications. Stakeholders drive the development of new plug-ins and support quality control. The documentation coordinator insures complete and consistent documentation of plug-in components across all teams.

2.2.3 Data Team

The Data Team is responsible for all aspects of data used in ENSITE. This task includes identifying and obtaining authoritative data, managing the storage and manipulation of data, and assuring compliance with data standards. All data used by plug-ins must be managed by the Data Team.

2.2.4 Core-Software Team

ENSITE's core software is the foundation of its overall software capability. Its core software runs the graphical user interface (GUI) and the software necessary to ingest data and scripts, work with databases, and display data and analyses on maps. The Core-Software Team is responsible for programing and delivering the ENSITE core software capability.

2.3 Development workflow

The workflow of plug-in development consists of four general steps, as illustrated in Figure 3.

Figure 3. Plug-in development workflow, from left to right.

Step 1: Conceptualize, research, and design. All the plug-ins currently featured in ENSITE were originally identified as necessary capabilities from an end user community. Through interactions with Army stakeholders, ENSITE developers identified a necessary capability, performed the necessary research, and produced a conceptual design for the plug-in. It is important to note that research is a key component to developing each capability. The novel nature of ENSITE and the automation of the analyses proposed for plug-in development require (a) using cutting-edge geospatial analysis techniques, (b) a deep understanding of Army doctrine, and (c) the ability to identify the most appropriate mode for accomplishing the goal (i.e., identifying both data and scripting environments).

Step 2: Write code. When developing analytical capabilities, developers must write the code to be compatible with the capabilities of ENSITE's core software. Developers must also test the code by using sample datasets for quality assurance, with input from both the Data Team and Core-Software Team. This quality assurance work is often characterized as an iterative testing and debugging phase. To do this work, the developer must follow a set of metadata guidelines for necessary documentation.

Step 3: Integrate with ENSITE software. After an individual plug-in developer finishes his or her code and has tested it on sample datasets to ensure accuracy, the next step is to fully integrate it within the core software and perform quality control. The Core-Software Team handles the majority of the integration, but the developer is responsible for ensuring the output (analyses) meet user expectations.

Step 4: Document. Developers are expected to provide a minimum amount of documentation directly in the code. Additionally, the developer works with the documentation coordinator to maintain accurate records of workflow steps 1-3. These records not only serve as metadata, but they also feed ENSITE program briefings.

3 Plug-in Requirements

3.1 Conceptualize, research, and design

Plug-in development begins with identification of a useful (or necessary) capability. Often, these capabilities are discovered through the ENSITE team's interaction with potential end users within the Army. Routine engagement with the active duty, end-user community has been critical to a developer's understanding of Army needs and subsequently, their creation of useful analytical tools. When conceptualizing a plug-in, the developer must explicitly identify the purpose of the plug-in, what analysis function(s) it will perform, and what connections it may have to previous plug-ins. After answering these basic questions, the plug-in developer moves forward into the research phase.

The research phase of plug-in development varies in length and intensity, depending on the plug-in capability needed and its complexity. Even baseline capabilities (such as calculation of terrain slope) require careful research. Although the mathematical basis for calculating slope from elevation data is very well established, context and details for the calculation are important. For instance, based on a survey of Army field manuals (FMs), the manuals use both degrees (FM 3-21.10, B-15; FM 3-21.38, 4-5 and 4-29) and percentages (FM3-21.10, 3-20; FM 3-22.90, 5-25) when describing terrain. Confusion between degrees and percentage could cause a simple slope calculation to be completely incorrect (and thus misleading). Even if a single answer cannot be found in doctrine, understanding these known issues is crucial to providing trustworthy and accurate analyses.

More complex analyses present even greater challenges. For instance, when the developer begins to incorporate the slope outputs into more sophisticated analyses (e.g., understanding possible corridors of ingress or egress), much more work is required. These more complex problems require a deeper understanding of related Army doctrine, physical specifications of vehicles, and novel applications of spatial science and statistics in order to accurately represent physical terrain.

Design considerations include the following questions:

- How will a plug-in perform the necessary analysis?

- What coding environment best meets the skills of the developer and the need to address a given problem?
- What are the general procedural steps involved in using that code?
- What inputs are required from the user (through the GUI) or as data?

The design phase requires close collaboration with both the Data Team and Core-Software Team, because the attributes and availability of critical data often shape plug-in design, and analysis functions drive software capabilities.

3.2 Code development

3.2.1 Coding choices, communication, and integration

Developers have the ability to write code as they desire. The key to this independence is for developers to simultaneously have clear and frequent communication with the other teams.

ENSITE's core software acts as an intermediary and translator between (a) data storage and data preparation, (b) a plug-in, and the display/storage of outputs. This approach allows plug-in developers to work in any scripting language they desire. They just need to work with the Core-Software Team to ensure proper integration. Currently, the core-software supports development in the following three languages/environments: R (any version),[*] Python (versions 2 and 3),[†] and Esri's[‡] Model Builder (ArcMap 10.4[§]). The languages of R and Python are preferred due to their relative stability, scalability, and troubleshooting ease. Moreover, development in R and Python is free, whereas the various Esri products have licensing costs. The Army currently owns approximately 13,000 ArcGIS licenses. It is one of the primary geospatial suites used Army-wide and thus, it was included as a plug-in development option despite its high licensing costs.

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* R is an open-source software that provides a wide variety of statistical and graphical techniques, and it is highly extensible. One of R's strengths is the ease with which well-designed publication-quality plots can be produced (https://www.r-project.org/about.html).

† Python is described as "powerful, fast, plays well with others, runs everywhere, and is friendly and easy to learn" (https://www.python.org/about).

‡ Esri is an international supplier of geographic information system software, web GIS, and geodatabase management applications and is headquartered in Redlands, CA (www.esri.com).

§ http://www.esri.com/en/arcgis/products/arcgis-pro/resources/arcmap-resources

The Data Team mandates a strict adherence to the Army's Ground-Warfighter Geospatial Data Model (GGDM). Developers need to coordinate with the Data Team regarding all input and output data. GGDM will dictate all data schema elements including naming conventions, formats, and projections.

To help facilitate communication between the teams, standardized metadata helps developers to convey the specific data and processes necessary for each analysis. This metadata allows for easy reference by ENSITE's core software to automatically understand what inputs it must provide the plug-in code (e.g., static data and user input from the user interface), and how to store and visualize the eventual outputs. For example, the Avenues of Approach plug-in tool is designed to identify mobility corridors for specific types of troops over specific terrain. Required inputs include a DEM, unit type (derived from user interface), unit size (from user interface), base location (from user interface and geodatabase), analysis radius (from user interface), and transportation infrastructure, soils, weather, and hydrography (from geodatabase).

3.2.2 Code repository

Many of ENSITE's analysis plug-ins will utilize the same basic pieces of functionality—for instance, the ability to pull data from or export it into a file geodatabase or the creation of user-defined buffers from a central point. To save development time and to ensure uniformity of code, the Analysis Team established a code repository where established pieces of commonly used code are accessible for all.

Any section of code accomplishing a discrete task (i.e., any piece of code that could live as a stand-alone tool) was bundled into a "function." This bundling allows for a greater ease of interoperability and less margin for error when foundation capabilities (such as slope) are used as components in more complex tools. Rather than simply inserting a given code snippet, referencing a function will allow for making changes to the original code without requiring complicated manual changes to all subsequent tools. The repository is maintained and managed by the Analysis Team.

3.3 Integration

The Analysis Team is responsible for quality assurance, meaning that each plug-in is stable and able to be used in any appropriate situation. As such,

the team performs a series of tests to check for basic scalability and stability. The tests aim to answer the following questions:

- Does the code do what it says it does?
- Is the actual code consistent with the associated metadata in the extensible markup language (xml)?
- Can the code work on multiple computers?
- Does the code work when appended to other existing analyses in the same language/environment?

Once the plug-in passes a basic quality assurance, the Analysis Team submits the plug-in to the Core-Software Team for integration within ENSITE's core software. The Core-Software Team handles extracting outputs from the geodatabases, projecting data to the appropriate place in the world, and "serving" the data to the analysis portion of the code. The core software takes outputs created by a given plug-in and performs the coordinate system transformation that is needed to make the output GGDM-compliant. The Core-Software Team is responsible for quality control (i.e., ensuring that products meet consumer expectations).

As it stands, integrating plug-ins to the core software means the plug-in developer and a core-software programmer must work together closely. Developers are encouraged to create capabilities outside the current status quo. ENSITE is a research effort and in the research stage, plug-ins are innovative prototypes. In the future beyond the research and prototype phases, each team would develop standards and quality assurance/quality control procedures to apply in both intra- and inter-team settings. There must be close coordination between all three teams (Analysis, Data, Core Software) in order to assure viability, scalability, and compliance when moving out of the prototype phase toward full integration.

3.4 Documentation

To manage the development of ENSITE and its capabilities, documentation is important. In order to fulfill the research needs of preparing regular progress reports, general documentation was managed through the Documentation Coordinator. This centralized management coordinator ensures

that each step of the workflow is equivalently documented by each developer (e.g., literature reviews, assumption). Centralized documentation management also provides project team managers with a single point-of-contact for their documentation needs. The Documentation Coordinator routinely generates plug-in reports (generally 1–2 pages in length) to describe the plug-in's concept, design, results, and a demonstration of how to use the tool. These reports were routinely used in program briefing materials.

Within the code, developers provided commentary describing the coded steps in common language. These comments are primarily used in quality assurance tests and would provide the following information:

- Name and contact information of author(s).
- Applicable dates (started, beginning of testing, submission, dates of major edits, etc.)
- Language and version used.
- Problem to be solved.
- Data, software, add-ons, or packages necessary to run the code successfully.
- Analysis that is taking place in the code.
- Conclusions that the developer has drawn from the development process.

4 Results and Way Forward

4.1 Current plug-ins

ENSITE research to date has produced the following 10 plug-ins that can assist ENSITE's core software to create specific site location analyses. A summary of each plug-in is given in the subsections below, examples of each are given in Section 4.2, and factsheets with additional information and illustration are presented in Appendix A.

4.1.1 Avenues of Approach

Identifies mobility corridors (unrestricted, restricted, and severely restricted areas) for specific types of force by incorporating slope, soil type, moisture, and land cover data.

4.1.2 Climate Means

Creates climate graphs for 10 variables with potential climate-related consequences and effects that support decision making for CB siting (e.g., building materials).

4.1.3 Engineering Report

Agglomeration of multiple analytical tools. Provides easy access to pertinent engineering information in a single report that includes building materials, site conditions, natural hazards, and regional climate trends.

4.1.4 Engineering Soil Properties

Provides a rough assessment of soil behavior for stability and constructability by analyzing soil permeability, compression, and sheer strength.

4.1.5 Golden Hour

Identifies travel distance from a site by medical evacuation (medevac) flights by helicopter. Accounts for flight restrictions due to political and topographic factors.

4.1.6 Heritage Sites

Generates an index of internationally recognized cultural and natural sites within a defined region surrounding proposed locations.

4.1.7 HUB

Provides a suite of tools and processes to supply ENSITE components with consistent, reliable data that conforms to Army standards. The ENSITE HUB consists of three phases: Data Acquisition, Data Governance, and Data Processing.

4.1.8 Line of Sight

Generates a viewshed of visible points from one or more observer locations to enable integrated, terrain-driven, force protection analyses.

4.1.9 Potential Road Zones

Identifies land areas suitable for roads by using remotely sensed data and a combination of engineering soil properties.

4.1.10 Spatial Nodes of Attraction

Identifies the socio-spatial conditions in urban areas that foster and promote the formation of crowds based on the combination of open space and sociocultural characteristics.

4.2 Plug-in examples

Listed below are detailed examples for all 10 plug-in tools currently in development. As noted above, these examples also are documented more fully, including illustrations and listing of inputs and outputs, in the appendix included with this report.

4.2.1 Avenues of Approach

An Avenue of Approach (AOA) is an air or ground route taken by an attacking force that leads the force to achieve an objective or key terrain. AOAs are classified by type (mounted, dismounted, air, or subterranean), formation, and speed of the largest unit that can travel the AOA. Commonly, AOA is considered as a component of a terrain analysis. The most

common terrain analysis technique is OAKOC, an ordered approach consisting of a review of the following elements: Observation and Fields of Fire, Avenues of Approach, Key Terrain, Obstacles, and Cover and Concealment.

The ENSITE AOA plug-in tool determines the best areas of mobility for two forces—dismounted troops and M1 Abrams tank-mounted troops. Inputs to the AOA analysis include terrain (i.e., digital elevation model), land cover, and soil type. Level of maneuverability is then calculated based on values found in Army doctrine. For example, with a force type of M1 Abrams tanks, areas with a slope of 15° receive a score of 1 (unrestricted).

A user selects a candidate location(s) for analysis, selects the force type to be mapped, and sets a weighting factor for the importance of each input. The AOA analysis classifies each input as unrestricted, restricted or severely restricted based on the force type requirements. These classifications are then weighted according to user assigned importance.

4.2.2 Climate Means

The Climate Means tool create climatic graphs with the purpose of providing necessary information for a variety of applications. The tool considers ten variables (listed in appendix factsheet). Each graph represents the average monthly variable over 10 years (2006-2016) and 30 years (1986-2016) within a given area of interest (underlying data at a 0.5 decimal degree scale). This provides a comparison of climatic conditions over the short-term and the long-term. The ten climatic variables capture various aspects and patterns of weather for a given area. The data supports decision making with potential climate-related consequences and effects. Building materials, for example, are often selected based on climatic conditions. The tool reduces the time needed to produce climatic data in a usable fashion for any landmass location in the world.

ENSITE users select a region of interest. The Climate Means tool pulls location-specific data from global landmass climatic coverages to generate regional climate graphs. ENSITE software saves the graphs as image files to increase their transferability.

4.2.3 Engineering Report

The Engineering Report provides easy access to pertinent engineering information, allowing users to obtain information for their location of interest in a single report. The Engineering Report is not intended to make engineering decisions for engineers or commanding officers. Instead, it supplements the information gained from field exploration and the engineer's/commanding officer's own knowledge. In many cases, once a site is selected, the engineer may have little knowledge of the site, its regional climate, or construction practices relevant to the location. However, the urgency of military site selection and the time availability of the engineer/commanding officer often does not allow for the research and time required to obtain this data.

ENSITE contains tools for determining values that are relevant for performing an engineering analysis and making decisions. Each tool uses mapped raster values based on global data. The Engineering Report tool pulls data from select ENSITE engineering tools to populate a report. There are four sections of the ENSITE Engineering Report—building materials, site conditions, natural hazards, and regional climate trends.

4.2.4 Engineering Soil Properties

The main engineering properties of soils are permeability, compressibility, and sheer strength. These properties characterize soil behavior for stability and constructability. But the tests required for determination of engineering properties are generally elaborate and time consuming. Sometimes only a rough assessment is needed. The Engineering Soil Properties tool creates an index of soil types that are indicative of specific engineering properties. Soils are classified and identified based on index properties. The eight soil properties reported by the Engineering Soil Properties Tool are listed below:

- material
- material code
- vertical foundation pressure
- lateral bearing pressure
- coefficient of friction
- cohesion (as compacted)
- cohesion (saturated)
- effective stress friction angle

Many soil properties used for construction design are not intrinsic to the soil type; instead, a soil's properties will vary depending on various conditions. In-situ stresses, the presence of water, and the rate and direction of loading can all affect the behavior of soils. Prior to evaluating the properties of a given soil, it is important to determine the existing conditions as well as how those conditions may change over the life of the construction project.

4.2.5 Golden Hour

This analysis plug-in automatically eliminates those locations within no-fly zones as well as those areas at elevations greater than 10,000 feet above sea level. The height restriction is because it is assumed that medevac aircraft do not operate at elevations higher than 10,000 feet, due not only to performance characteristics of the aircraft but also due, even more so, to the high-altitude atmospheric impacts on the patients being evacuated. Distance calculations are based on the Great Circle of the Earth theorem. The UH-60 Black Hawk and the CH-47 Chinook helicopters are the aircraft assumed to be conducting medevac operations.

Within the ENSITE software, the user specifies candidate base location(s) on a map. The Golden Hour plug-in then draws zones of 0.5, 1.0, and 1.5 hours around each base location for Black Hawk and Chinook transport.

4.2.6 Heritage Sites

The Hague Convention of 1954 (Hague 1954) prohibits the destruction of, or construction at, certain types of cultural and natural heritage sites during a conflict. The ENSITE Heritage Sites plug-in highlights those heritage sites as no-build areas, and it also assists in their protection by placing a buffer of 100 m radius around them. The distance of 100 m was selected based on knowledge of buffer-zone distances used by other international organizations that are interested in site protection and knowledge of a proven, practical distance for site protection from arms fire and vibrations of moving vehicles. Military significance or criticality of the site is not an analysis factor within the tool.

4.2.7 HUB

ENSITE HUB is a suite of tools and processes to provide ENSITE components with consistent, reliable data that conforms to Army standards. The

components of ENSITE HUB can be broken into the following three categories:

1. **Data Acquisition** includes the process to obtain required data for ENSITE analyses from various sources.
2. **Data Governance** covers both a review of data sources to ensure they meet robust standards and an identification of Army Authoritative Data Sources.
3. **Data Processing** involves transforming data for use in ENSITE Analyst. This includes changing the schema of vector data to match the Ground-warfighter Geospatial Data Model (GGDM).

Through the tools within ENSITE HUB, a user with little or no GIS experience can expect to go from initial data collection to a completed, functional Mission Folder in a few hours.

4.2.8 Line of Sight

The Line of Sight (LoS) plug-in generates a series of points that are either visible or not visible from one or more observer locations. The location (i.e., x, y, and z coordinates) of all observer and viewpoints are defined by the user. In the example shown in, a man standing at the observer location would not be able to see a vehicle on the other side of the hill, but could see the tower located behind the hill. Therefore, the man does not have LoS to the vehicle, but he does have LoS to the tower. The technique is likened to holding a length of thread between two locations. If the thread, held straight, doesn't encounter any obstacles, then the LoS is valid.

To run the LoS plug-in tool in ENSITE, the user selects candidate locations, or observer points, on the map. For each location, sight rings for selected weapons platforms will appear. In addition to the site rings, a viewshed analysis generates a raster of areas believed to be visible based upon local topography.

4.2.9 Potential Road Zones

The Potential Road Zones plug-in identifies land areas suitable for roads. The tool is not intended to make engineering decisions for engineers or commanding officers, but instead it supplements the information obtained from field exploration and the engineer's/commanding officer's own

knowledge. A “road zone” is considered to be suitable as a thoroughfare, route, or way on land between two places that has been paved or otherwise improved to allow travel by foot or some form of conveyance, including a motor vehicle.

ENSITE users select a region of interest, and the Potential Road Zones tool calculates the best areas for development of roadways based on current soil and terrain conditions. Users weigh the significance of soil and terrain conditions based on their mission requirements (i.e., type of road and types of travelers).

4.2.10 Spatial Nodes of Attraction

The Spatial Nodes of Attraction (SNoA) tool identifies the socio-spatial conditions in urban areas that foster and promote the formation of crowds. Areas with a greater probability that people will coalesce are identified by open space—sites that can host many people and have a social or cultural association within the city that reinforces the message of the crowd. Using geospatial and statistical analyses that describe those elements, SNoA predicts where people will gather.

The tool combines open spaces with geospatial data from Open Street Map® to indicate areas that contain multiple characteristics. SNoA is intended to alert commanding officers and decision makers to areas in a city where people are likely to gather, given the appropriate social and political conditions. Crowds—particularly protests and riots—can form quickly, and the information presented by SNoA plug-in’s predictions should supplement information obtained from field exploration and the engineer’s or commanding officer’s own knowledge. The tool is not intended to make decisions for engineers or commanding officers but instead, it augments other available information. The output is rendered as a heat map.

4.3 Next steps

As ENSITE research continues, the next steps will be improving the progress of developing plug-ins. A focus on process will facilitate the creation of novel, powerful, stable, and high-quality plug-ins. Changes in process will revolve around the dual goals of removing opportunities for errors and increasing quality of communication and collaboration between teams’ intertwined responsibilities.

Specific future steps include the following:

- Transitioning all plug-in development and version control tasks to be within a formal software control system that will track changes in code and coordinate work on those codes among multiple people and teams.
- Refining the stages of (a) plug-in creation and (b) plug-in transition from prototype to fully scalable and finalized analytical application.
- Creating automated quality assurance and quality control test scripts.
- Expanding analytical capabilities by pursuing separate funding from stakeholders to develop more novel and/or research-intensive plug-ins.

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The Hague. "Convention for the Protection of Cultural Property in the Event of Armed Conflict." Netherlands: The Hague, 1954.

Appendix A: ENSITE Plug-In Factsheets

While short descriptions of existing prototype plug-ins have been provided, users could find a more detailed description (including screen shots and other illustrations) to be very useful. The factsheets reproduced in Appendix A provide a deeper look at the technical and strategic level details for each plug-in.

Avenues of Approach factsheet

U.S. ARMY CORPS OF ENGINEERS

ENSITE Analysis Tool
Avenues of Approach

BUILDING STRONG®

8 May 2017

Summary
Identifies mobility corridors (areas of unrestricted, restricted, and severely restricted) for specific types of force using slope, soil type, moisture, and land cover.

Overview
An Avenue of Approach (AOA) is an air or ground route of an attacking force leading to an objective or key terrain. AOAs are classified by type (mounted, dismounted, air, or subterranean), formation, and speed of the largest unit that can travel along it. Commonly, AOA is considered as a component of a terrain analysis. The most common terrain analysis technique is OAKOC, an ordered approach consisting of a review of the following elements: Observation and Fields of Fire, Avenues of Approach, Key Terrain, Obstacles, and Cover and Concealment. Figure 1 exemplifies the importance of an AOA analysis.

Figure 1. Failure to adequately consider avenues of approach leaves deployed force infrastructure vulnerable to opposition manuvers.
Source: https://www.youtube.com/watch?v=n3WCSAYHLpA

The ENSITE AOA analysis tool determines the best areas of mobility for two forces—dismounted troops and M1 Abrams tank. Inputs to the AOA analysis include terrain (i.e. digital elevation model), land cover, and soil type. Level of maneuverability is then calculated based on values found in Army doctrine. For example, with a force type of M1 Abrams tanks, areas with a slope of 15° receive a score of 1 (unrestricted), etc. The tool is not intended to make engineering decisions for engineers or commanding officers. Instead, it supplements the information obtained from field exploration and the engineer's/commanding officer's own knowledge.

Running the Tool in ENSITE
A user selects a candidate location(s) for analysis, selects the force type to be mapped, and sets weights for the importance of each input. The AOA analysis classifies each input as unrestricted, restricted or

severely restricted based on the force type requirements. These classifications are then weighted according to user assigned importance. Figure 2 illustrates the result of an example AOA analysis performed within ENSITE.

Figure 2 displays the maneuverability of a M1 Abrams tank across the landscape. The 'green' unrestricted areas represent zones where the tank can freely maneuver. Conversely, 'red' severely restricted areas represent zones where maneuverability is very limited due to terrain, soil, and/or land cover conditions.

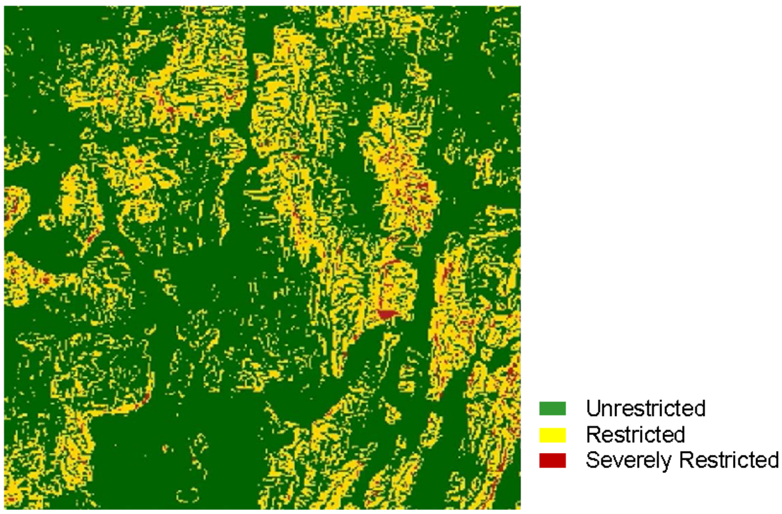

Figure 2. AOA tool output demonstrates potentially vulnerable corridors for maneuver.

Metadata

Author/POC:	Elle Williams
Language:	R
Inputs:	Digital Elevation Model, Land cover raster (VISNAV 1), Soil raster (MAAX Soil Scape), and layer weights
Outputs:	Raster map of maneuverability
References:	US Army. FM 34-130, Intelligence Preparation of the Battlefield, (Appendix B).

Climate Means factsheet

ENSITE Analysis Tool

Climate Means

U.S. ARMY CORPS OF ENGINEERS BUILDING STRONG®

4 May 2017

Summary
Creates climate graphs for ten variables that support decision making with potential climate-related consequences and effects (e.g. building materials).

Overview
The Climate Means tool create climatic graphs with the purpose of providing necessary information for a variety of applications. The tool considers ten variables—listed in Table 1. Each graph represents the average monthly variable over ten (2006-2016) and thirty (1986-2016) years in a given area of interest (underlying data at a 0.5 decimal degree scale). This provides a comparison of climatic conditions over the short-term and the long-term. The ten climatic variables capture various aspects and patterns of weather for a given area. The data supports decision making with potential climate-related consequences and effects. Building materials, for example, are often selected based on climatic conditions. The tool reduces the time needed to produce climatic data in a usable fashion for any landmass location in the world. The tool is not intended to make engineering decisions for engineers or commanding officers. Instead, it supplements the information obtained from field exploration and the engineer's/commanding officer's own knowledge.

Table 1. Climate Variables

Climatic Variable	Units
Cloud Cover	Percentage
Diurnal Temperature Range	Degrees Celsius
Frost Day Frequency	Days
Potential Evapotranspiration	Millimeters per Day
Precipitation	Millimeters per Month
Daily Mean Temperature	Degrees Celsius
Monthly Average Daily Minimum Temperature	Degrees Celsius
Monthly Average Daily Maximum Temperature	Degrees Celsius
Vapor Pressure	Hectopascals
Wet Day Frequency	Days

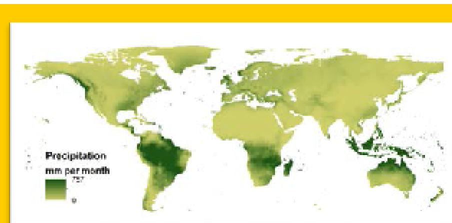

Figure 1. Average monthly precipitation in January over 10 years (2006-2016). Data produced from Harris et al. (2014).

Running the Tool in ENSITE
ENSITE users select a region of interest. The Climatic Means tool pulls location-specific data from global landmass climatic coverages to generate regional climate graphs. Figure 2 provides an example of a monthly precipitation graph. ENSITE software saves the graphs as image files to increase transferability of the outputs. The Climatic Means analytics are also part of the ENSITE Engineering Report. Refer to the Engineering Report factsheet regarding further details on this integration.

Engineer Research and Development Center

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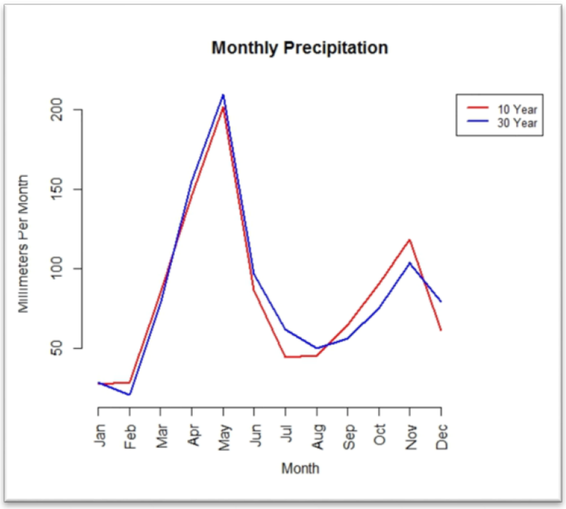


Figure 2. Climatic Means Tool Output for Regional Precipitation. The ten year trend line represents data from 2006 to 2016. The thirty year trend line represents data from 1986 to 2016. Data produced from Harris et al. (2014).

Metadata

Author/POC:	Elle Williams and Eric Kreiger
Language:	R
Inputs:	Global landmass climatic variables: cloud cover; diurnal temperature range; frost day frequency; potential evapotranspiration; precipitation; daily mean temperature; monthly average daily minimum temperature; monthly average daily maximum temperature; vapor pressure; and wet day frequency. Harris, I., Jones, P.D., Osborn, T.J. and Lister, D.H. (2014), Updated high-resolution grids of monthly climatic observations - the CRU TS3.10 Dataset. *International Journal of Climatology* 34, 623-642.
Outputs:	Graphs of climate variables
References:	Harris, I., Jones, P.D., Osborn, T.J. and Lister, D.H. (2014), Updated high-resolution grids of monthly climatic observations - the CRU TS3.10 Dataset. *International Journal of Climatology* 34, 623-642.

Engineering Report factsheet

U.S. ARMY CORPS OF ENGINEERS

ENSITE Analysis Tool

Engineering Report

BUILDING STRONG®

4 May 2017

Summary

Agglomeration of multiple analytical tools. Provides easy access to pertinent engineering information in a single report, including building materials, site conditions, natural hazards, and regional climate trends.

Overview

The Engineering Report provides easy access to pertinent engineering information—allowing users to obtain information for their location of interest in a single report. The Engineering Report is not intended to make engineering decisions for engineers or commanding officers. Instead, it supplements the information gained from field exploration and the engineer's/commanding officer's own knowledge. In many cases, once a site is selected, the engineer may have little knowledge of the site, regional climate, or construction practices relevant to the location. The urgency of military site selection and time availability of the engineer/commanding officer often does not allow for the research and time required to obtain this data.

ENSITE contains tools for determining values that are relevant for performing an engineering analysis and making decisions. Each tool uses mapped raster values based on global data. The Engineering Report tool pulls data from select ENSITE engineering tools to populate a report. There are four sections of the ENSITE Engineering Report—building materials; site conditions; natural hazards; and regional climate trends.

Building Materials: Supports the selection of proper building materials for the specified site based on susceptibility to decay. Using the ENSITE Material Decay tool, the report identifies recommended materials and materials *not* recommended for use. ENSITE features additional plug-ins designed to identify the most accessible location for obtaining recommended materials.

Site Conditions: Provides a site specific initial screening of soils including their typical engineering properties and land uses. This section contains characteristics that vary with time - it is intended to be a screening tool. Field tests should confirm the reported values.

Natural Hazards: Provides characteristics of floods, earthquakes, cyclone winds, liquefaction, tsunamis, landslides, and volcanos. Identifying potential hazards supports the determination of structural loads and risk of an event occurring. Characteristics are extracted from the ENSITE Natural Hazards tool.

Regional Climate Trends: Extracts climatic condition data from the ENSITE Climate Means tool. These conditions include mean monthly temperature, monthly diurnal temperature, monthly precipitation, monthly wet day frequency, monthly vapor pressure, monthly potential evapotranspiration, and monthly cloud cover averaged for each month and plotted for a 10 and 30 year period.

Engineer Research and Development Center

ERDC *Innovative solutions for a safer, better world*

Running the Tool in ENSITE

An engineering report is automatically generated any time a user proposes a new site location for analysis. The Engineering Report tool agglomerates analytics from other ENSITE engineering tools to populate the report. These other tools include: Material Decay, Engineering Soil Properties, Land Use, Natural Hazards, and Climate Means. Refer to the individual factsheets on each of these tools for further details on each tool.

Metadata

Author/POC:	Eric Kreiger and Elle Williams
Language:	--
Inputs:	ENSITE Material Decay Tool, ENSITE Engineering Soil Properties Tool, ENSITE Land Use Tool, ENSITE Natural Hazards Tool, and ENSITE Climate Means Tool
Outputs:	PDF report
References:	Unified Facilities Criteria (UFC) 1-200-01, DoD BUILDING CODE (GENERAL BUILDING REQUIREMENTS), 1 April 2016. Unified Facilities Criteria (UFC) 3-220-01, DoD GEOTECHNICAL, 1 November 2012. Unified Facilities Criteria (UFC) 3-301-01, DoD STRUCTURAL ENGINEERING, 1 June 2013. Unified Facilities Criteria (UFC) 3-310-04, DoD SEISMIC DESIGN OF BUILDINGS, 1 June 2013. Army Techniques Publication (ATP) 3.34.81, DoD Engineer Reconnaissance, March 2016. Flood Resistant Design and Construction, ASCE Standard 7. 2015. American Society of Civil Engineers. International Building Code (IBC). 2012. International Code Council. Table 1802.2. American Association of State Highway and Transportation Officials (AASHTO) Load Resistance Factor Design (LRFD) Bridge. 2012. American Association of State Highway and Transportation Officials.

Engineering Soils factsheet

ENSITE Analysis Tool

Engineering Soil Properties

U.S. ARMY CORPS OF ENGINEERS BUILDING STRONG®

4 May 2017

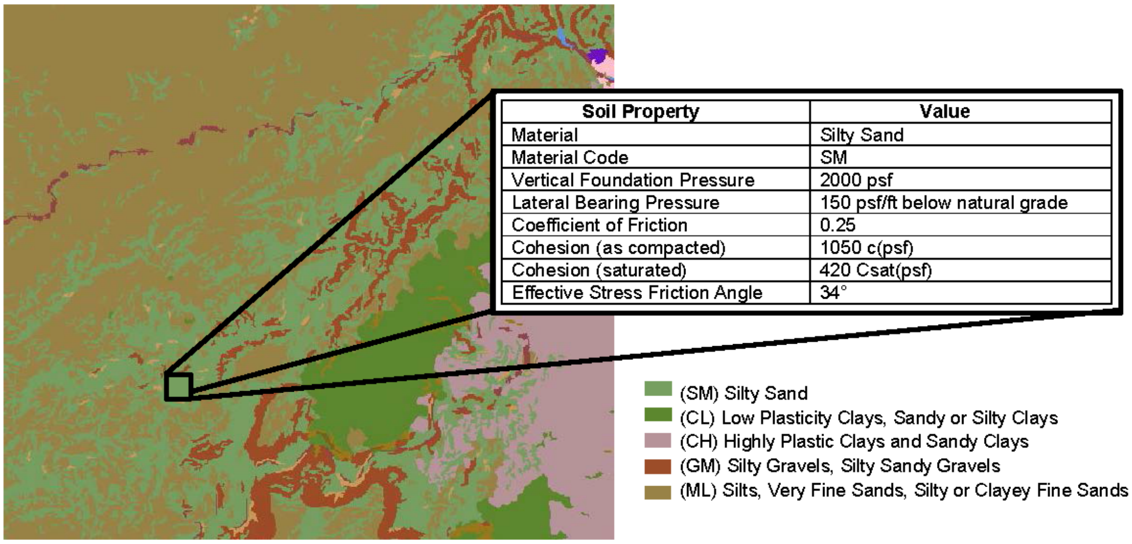
Summary
Provides a rough assessment of soil behavior for stability and constructability by analyzing soil permeability, compression, and sheer strength.

Overview
The main engineering properties of soils are permeability, compressibility, and sheer strength. These properties characterize soil behavior for stability and constructability. But the tests required for determination of engineering properties are generally elaborate and time consuming. Sometimes only a rough assessment is needed. The Engineering Soil Properties tool creates an index of soil types indicative of engineering properties. Soils are classified and identified based on index properties. The eight soil properties reported by the Engineering Soil Properties Tool are listed below.

- Material
- Material Code
- Vertical Foundation Pressure
- Lateral Bearing Pressure
- Coefficient of Friction
- Cohesion (as compacted)
- Cohesion (saturated)
- Effective Stress Friction Angle

Many soil properties used for construction design are not intrinsic to the soil type, but vary depending on conditions. In-situ stresses, the presence of water, and rate and direction of loading can all affect the behavior of soils. Prior to evaluating the properties of a given soil, it is important to determine the existing conditions as well as how conditions may change over the life of the construction project. Moreover, this tool is not intended to make engineering decisions for engineers or commanding officers. Instead, it supplements the information obtained from field exploration and the engineer's/commanding officer's own knowledge.

Running the Tool in ENSITE
ENSITE users select a region of interest and the Engineering Soil Properties tool generates the soil properties report. Figure 1 provides an example output. The Engineering Soil Properties outputs are utilized by other ENSITE tools—including Potential Road Zones and Natural Hazards (forthcoming). The outputs are also part of the ENSITE Engineering Report. Refer to the respective ENSITE factsheets regarding further details on these integrations.



Soil Property	Value
Material	Silty Sand
Material Code	SM
Vertical Foundation Pressure	2000 psf
Lateral Bearing Pressure	150 psf/ft below natural grade
Coefficient of Friction	0.25
Cohesion (as compacted)	1050 c(psf)
Cohesion (saturated)	420 Csat(psf)
Effective Stress Friction Angle	34°

Figure 1. Example Engineering Soil Properties Tool Output

The soil map (Topographic Data Store, 2015) in Figure 1 depicts different soil types in a specified region. The table represents example tool output for the highlighted silty sand soil type. The Engineering Soil Properties tool estimates the soil property values based on soil indexing properties defined by IBC 2012 and Lindeburg 2014.

Metadata

Author/POC:	Eric Kreiger and Elle Williams
Language:	R
Inputs:	MAAX Soil Scape
Outputs:	PDF report of engineering soil property values
References:	International Building Code (IBC). 2012. International Code Council. Table 1802.2. Lindeburg, Michael R. 2014. Civil Engineering Reference Manual for the PE Exam. Table 35.12.

Golden Hour factsheet

ENSITE Analysis Tool
Medevac Golden Hour

U.S. ARMY CORPS OF ENGINEERS BUILDING STRONG®

4 May 2017

Summary
Identifies travel distance from a site for helicopter Medevac flights. Accounts for flight restrictions due to political and topographic factors.

Overview
The golden hour refers to a time period lasting for one hour, or less, following traumatic injury being sustained by a casualty or medical emergency, during which there is the highest likelihood that prompt medical treatment will prevent death. The Medevac Golden Hour tool is designed to identify areas that can be reached within an hour of an injury. The tool's analysis is limited to the pickup flight and patient load time considerations. Other elements of the medial evacuation system, pictured in Figure 1, are required for a complete medevac capability analysis. The Medevac Golden Hour tool supports site analysis by identifying what of the immediate region surrounding a proposed base location is reachable by air within one hour. The tool is not intended to make decisions for engineers or commanding officers, but instead supplements the information obtained from field exploration and the engineer's/commanding officer's own knowledge.

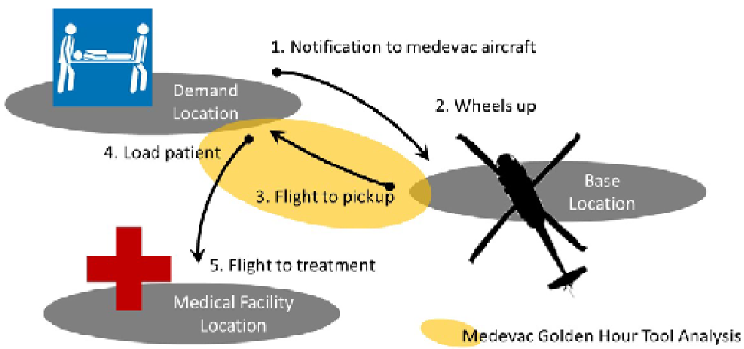


Figure 1. Medical Evacuation System

The analysis eliminates no-fly zones as well as areas with elevations greater than 10,000 feet above sea level. It is assumed that medevac aircraft do not traverse elevations greater than 10,000 feet due not only to performance characteristics of the aircraft but even more so due to the atmospheric impacts on the patients being evacuated. Distance calculations are based on the Great Circle of the Earth theorem. Aircraft assumed to be conducting medevac operations are the UH-60 Black Hawk and the CH-47 Chinook.

Speed is assumed to be the typical operating speed for the aircraft. Patient load time at the pickup location is said to be at least five minutes with a maximum of fifteen minutes based on subject matter expertise. Given

this level of uncertainty as well as the disregard for external factors affecting speed (e.g. weather), a Monte Carlo simulation determined the flight distance reachable within one hour for each aircraft type—including patient load time. The 50 percent quantile range is 199.9 km for a CH-47 Chinook and 233.3 km for a UH-60 Black Hawk. In other words, the median distance a Black Hawk can travel and load a patient within one hour is 233.3 km.

Running the Tool in ENSITE

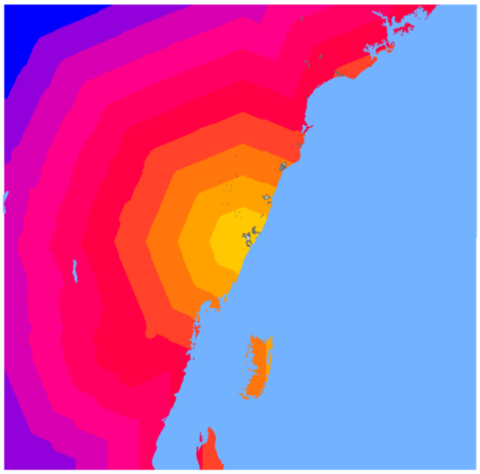


Figure 2 illustrates how travel distances are assumed to go around no-fly zones and elevations greater than 10,000 feet. From a proposed site location in a coastal city, the Golden Hour tool calculates travel times based on aircraft speed, no fly zones, and elevation limitations.

The user specifies candidate base location(s) on the map within ENSITE. The Medevac Golden Hour tool draws user specified time buffers around each site location based on the speed of the user selected aircraft (Black Hawk and/or Chinook).

Metadata

Author/POC:	Juliana Wilhoit and Kate Morozova
Language:	ESRI Model Builder
Inputs:	Digital terrain elevation, No fly zones, Target site location
Outputs:	Reachable distance buffers for UH-60 Black Hawk and CH-47 Chinook
References:	Center for Army Analysis

Heritage Sites factsheet

ENSITE Analysis Tool

Heritage Sites

U.S. ARMY CORPS OF ENGINEERS

BUILDING STRONG®

4 May 2017

Summary
Generates an index of internationally and nationally recognized cultural and natural sites within a defined region surrounding proposed locations.

Overview
The Hague Convention of 1954 prohibits the destruction of or construction on certain types of heritage sites (both cultural and natural) during a conflict. The Heritage Sites tool identifies those sites as no-build areas and places a 100-meter buffer around them to assist in their protection. A 100-meter buffer zone was selected based on buffer distances used by other organizations. The buffer zone also acts as a practical distance for protection from arms fire and vibrations of moving vehicles.

The Heritage Sites tool is useful for determining areas in which military forces should not build due to cooperative international treaties and agreements, U.S. laws, DoD policies, and Army regulations in place to protect cultural and natural resources. The tool generates a map of heritage sites by linking protected site categories from Open Street Map®, Protected Planet, and UNESCO's World Heritage List. Table 1 provides a selection of protected site types included within the analysis tool. Significance or criticality of the site is not an analysis consideration. Moreover, the tool is not intended to make decisions for engineers or commanding officers, but instead supplements the information obtained from field exploration and the engineer's/commanding officer's own knowledge. The tool outputs polygons rendered on a map, tagged with cultural and natural map objects, and categorized as no-build areas.

Table 1. Types of protected sites included in the Heritage Sites tool.

Cultural Sites		Natural Sites
Museum	Auditorium/Theatre	Heritage Landscape
Library	Community Centre	Viewshed/Viewpoint
Archive	Shipwreck	Nature Preserve/Reserve
Zoo/Aquarium	Cemetery/Graveyard	Park/Playground
Ruin/Archaeological Site	Observatory/Planetarium	National/Regional Park
Public Art	Religious Building/Site	Wildlife Sanctuary
Monument	Historic: Battlefield, Site, etc.	Botanic/Public Garden
Stadium	Hospital	Protected Area
Mausoleum/Memorial	School	Wetland

Running the Tool in ENSITE
The Heritage Sites tool is run in ENSITE software as part of data pre-processing. During the database initialization process, all heritage sites are identified. This ensures that all ENSITE analyses are in compliance with the protection of cultural and natural sites. Protected areas and their 100-meter buffers are then marked as no-build areas within the ENSITE software. Figure 1 provides example output.

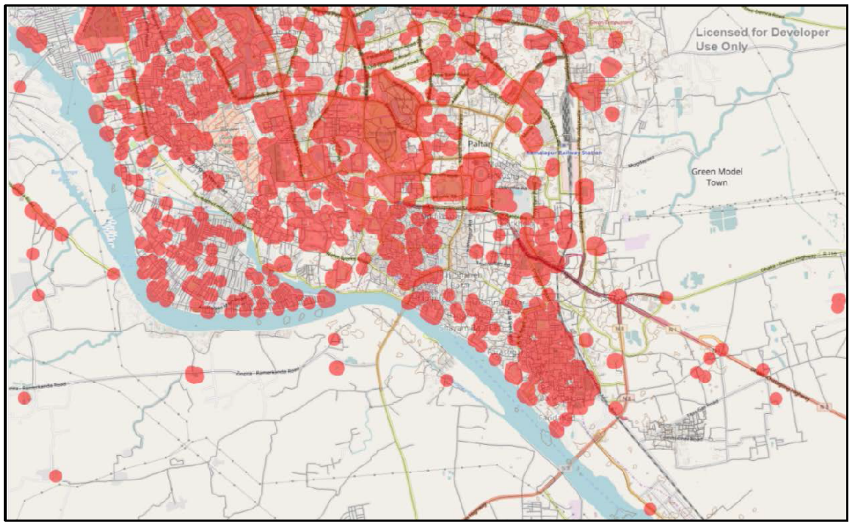


Figure 1. Heritage Sites tool outputs from ENSITE. The red highlighted areas bound all tagged cultural and natural sites with a 100-meter buffer. These red areas are considered no-build zones.

Metadata

Author/POC:	Kathryn O. Fay and Juliana M. Wilhoit
Language:	SQL
Inputs:	Open Street Map®, Protected Planet, UNESCO World Heritage List
Outputs:	Polygons of no-build areas
References:	Fay, Kathryn O. and George W. Calfas. "Heritage at Risk: Mapping as a Form of Protection and Preservation for Global Heritage Sites." In NATO Legal Gazette, Issue 38; 2017; In Press.

HUB factsheet

ENSITE
HUB: Data Acquisition

U.S. ARMY CORPS OF ENGINEERS BUILDING STRONG®

4 May 2017

Summary
A suite of tools and processes to provide ENSITE components with consistent, reliable data that conforms to Army standards. Consists of three phases: Data Acquisition, Data Governance, and Data Processing.

Overview
ENSITE HUB is a suite of tools and processes to provide ENSITE components with consistent, reliable data which conforms to Army standards. The components of ENSITE HUB can be broken into the following three categories:

1) **Data Acquisition** includes the process to obtain required data for ENSITE analyses from various sources.
2) **Data Governance** covers both a review of data sources to ensure they meet robust standards and an identification of Army Authoritative Data Sources.
3) **Data Processing** involves transforming data for use in ENSITE Analyst. This includes changing the schema of vector data to match the Groundwarfighter Geospatial Data Model (GGDM).

Through the tools in ENSITE HUB, a user with little to no GIS experience can expect to go from initial data collection to a completed, functional Mission Folder in a few hours.

HUB Organization: The Mission Folder
The central product of HUB is the Mission Folder. The format of the Mission Folder structure is fixed in order to allow for consistent development across mission areas. The Mission Folder segregates data based on its type—vector and raster. This is because GGDM is a vector standard and a GGDM compliant database cannot include raster data. The root of the Mission Folder contains three components that hold the inputs to ENSITE: "DataHUB" to contain the HUB outputs/analysis input data, "Studies" to contain analysis outputs, and "Supporting" to contain base maps, analyses, and imagery features (see Figure 1).

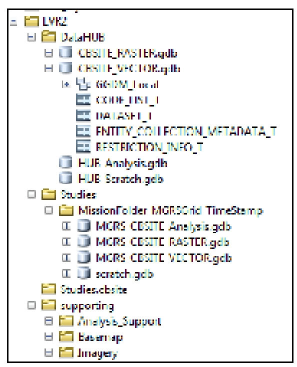


Figure 1. Screenshot of the Mission Folder for an Area of Interest Named LVR2.

Summary of Data Sources

Data	Summary	Source
Digital Terrain Elevation Data (DTED) Level 2	Digital Terrain Elevation Data (DTED) is a product derived from the Shuttle Radar Topography Mission (SRTM) in conjunction with NASA to create the first near-global set of land elevations. DTED Level 2 consists of 1 arc-sec data (approximately 30 meters), which is roughly equivalent to the contour information contained on a 1:50,000 scale topography map.	Army Geospatial Center
OpenStreetMap (OSM)	OpenStreetMap (OSM) is a global mapping platform using volunteered geographic information to create a free and editable map of the world. OSM has grown to over 2 million users who contribute data. OSM values local knowledge and contributors use aerial imagery, GPS devices, and low-tech field maps to verify that OSM data is accurate and up to date. The underlying data is viewed as the primary product – not the map itself.	Open StreetMap Foundation
SoilScape	The SoilScape Unified Soils Classification System Layer (Usoils) provides information on soil type based on the Unified Soils Classification System (USCS), which is an engineering properties based system. Attribution includes a two letter soils identifier and a brief text description of the soil type.	Army Geospatial Center (AGC)
UNESCO Sites	This dataset is from the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage program and contains the coordinates for UNESCO sites. The sites are selected as having global significance to culture, science, or history. There are 1,052 UNESCO sites around the world that are protected by international treaty.	UNESCO
VISNAV LULC	The National Geospatial-Intelligence Agency (NGA) produces several land use/land cover (LULC) products which are available at several resolutions ranging from 5 meters to 30 meters. Each product supports a variety of applications such as broad area search, cartographic vegetation mapping, vehicle mobility modeling, engineering planning, and humanitarian disaster response.	AGC via Common Map Background (CMB)
World Database on Protected Areas (WDPA)	World Database on Protected Areas (WDPA) is a comprehensive data source of protected areas which is updated monthly and was established in 1981. The WDPA contains protected lands information from parities including private land conservation groups, local communities, indigenous peoples, and national land management agencies.	WDPA Website: ProtectedPlanet.net

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Line of Sight factsheet

U.S. ARMY CORPS OF ENGINEERS

ENSITE Analysis Tool
Line of Sight

BUILDING STRONG®

4 May 2017

Summary
Generates a viewshed of visible points from one or more observer locations to enable integrated, terrain-driven force protection analyses.

Overview
The Line of Sight (LoS) tool generates a series of visible or non-visible points from one or more observer locations. The location (x, y, and z coordinates) of all observer and viewpoints are defined by the user. In Figure 1, a man standing at the observer point would not be able to see a vehicle on the other side of the hill, but he could see the tower. Therefore, the man does not have LoS to the vehicle, but does have LoS to the tower. The technique is similar to holding a length of thread between two counters. If the thread, held straight, doesn't encounter any obstacles, the LoS is valid.

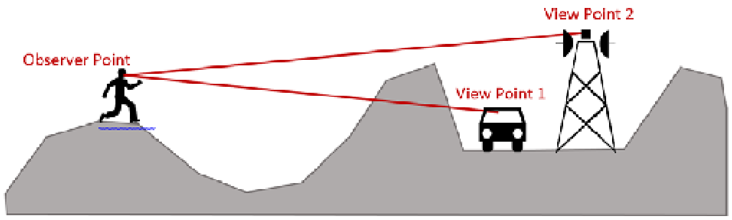

Figure 1. Line of Sight

The LoS tool is useful for determining areas which can be engaged with direct fire weapons systems. The tool uses digital elevation model (DEM) data to represent an approximation of terrestrial elevation. It does not factor in circumstantial obstructive details such as buildings and trees. This limitation should be considered when considering the profile. Multiple observer and associated viewpoints can be defined and calculated in a single "run" of the tool. The output is a viewshed rendered as visible points with a table that contains conclusions of "visible" or "non-visible" for each view point from a defined observer point (see Figure 2). The tool is not intended to make decisions for engineers or commanding officers, but instead supplements the information obtained from field exploration and the engineer's/commanding officer's own knowledge.

Running the Tool in ENSITE
The user selects candidate locations (i.e. observer points) on the map. For each candidate location, sight rings for selected weapons platforms appear. Running the LoS tool from the interface toolbar generates a raster of areas determined to be visible based upon local topography. Figure 2 provides example output for three candidate locations/observer points. Visible black dots represent valid LoS view points for their respective observer point.

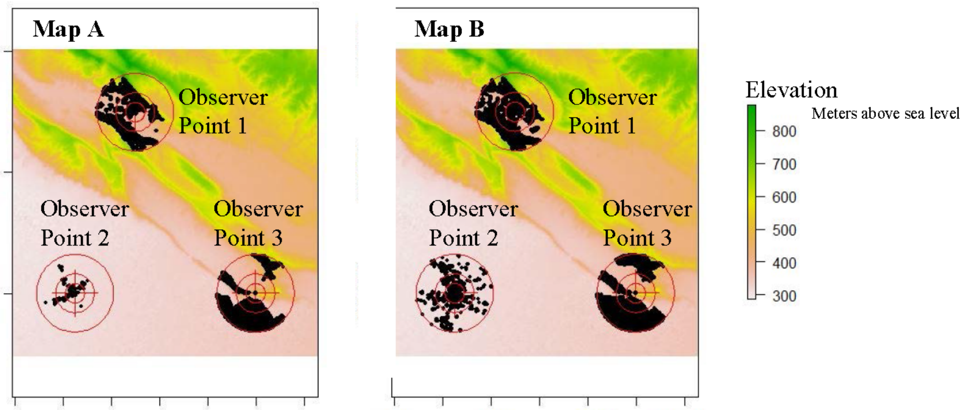

Figure 2. LoS Tool Outputs from ENSITE

In map A, the observer point is defined as 1.5 meters above ground level (i.e. the average height of a human) with all viewpoints at ground level. In map B, the observer point is defined as 5.0 meters above ground level (i.e. an artificially elevated position/guard tower) with all viewpoints at ground level. The concentric red circles are placed at 400, 800, and 1600 meters from the observer point, based on general effective ranges of primary small arms weapons systems. Note that “Observer Point 2” is located on flat terrain. The addition of a guard tower makes a much more significant difference than in the more mountainous Observer Points 1 and 3.

Metadata

Author/POC:	Kate Morozova
Language:	R
Inputs:	Digital elevation, weapon ranges, observer point location (x, y, and z coordinates), target height
Outputs:	Raster of visible and non-visible converted to both a polygon image and tabular data
References:	---

Potential Road Zones factsheet

ENSITE Analysis Tool

Potential Road Zones

U.S. ARMY CORPS OF ENGINEERS

BUILDING STRONG®

4 May 2017

Summary

Identifies land areas suitable for roads using remotely sensed data and a combination of engineering soil properties.

Overview

The Potential Road Zones tool identifies land areas suitable for roads. the tool is not intended to make engineering decisions for engineers or commanding officers, but instead supplements the information obtained from field exploration and the engineer's/commanding officer's own knowledge. A "road zone" is considered to be suitable as a thoroughfare, route, or way on land between two places that has been paved or otherwise improved to allow travel by foot or some form of conveyance, including a motor vehicle. The tool considers six soil properties from the International Building Code (2012) along with slope to determine areas that are most suited for roadways. The six soil properties are listed below.

- Vertical Foundation Pressure
- Lateral Bearing Pressure
- Coefficient of Friction
- Cohesion (as compacted)
- Cohesion (saturated)
- Effective Stress Friction Angle

The tool does not analyze urban environments because of data limitations. Nor does it directly account for structural elements, such as bridges or overpasses. Other factors not included in the analysis to consider include environmental impact of the road, costs, availability of materials, and safety. This highlights the value of the tool's analyses when engineers are projecting the level of effort required for road construction.

Running the Tool in ENSITE

ENSITE users select a region of interest and the Potential Road Zones tool calculates the best areas for the development of roadways based on current soil and terrain conditions. Users weigh the significance of soil and terrain conditions based on their mission requirements (i.e. type of road and travelers). Figure 1 provides an example output from the tool. It shows the regional suitability for roadway development given current conditions.

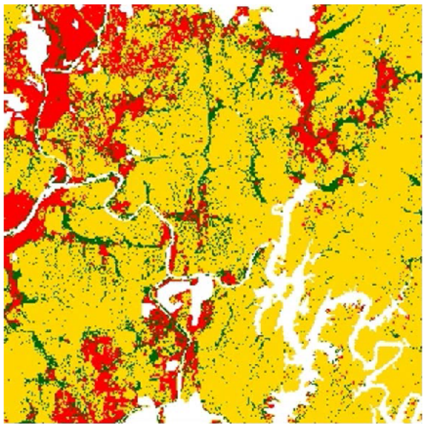

Figure 1. Example Potential Road Zones tool output in a very mountainous region with slope weighted at 60% and soil properties at 40%.

Metadata

Author/POC:	Eric Kreiger and Elle Williams
Language:	R
Inputs:	Soil raster (MAAX Soil Scape), DEM raster, IBC table
Outputs:	Raster of potential road zones
References:	International Building Code (IBC). 2012. International Code Council. Table 1802.2. Lindeburg, Michael R. 2014. Civil Engineering Reference Manual for the PE Exam. Table 35.12

Spatial Nodes of Attraction factsheet

ENSITE Analysis Tool

Spatial Nodes of Attraction

U.S. ARMY CORPS OF ENGINEERS BUILDING STRONG®

4 May 2017

Summary
Identifies the socio-spatial conditions in urban areas that foster and promote the formation of crowds.

Overview
The Spatial Nodes of Attraction (SNoA) tool identifies the socio-spatial conditions in urban areas that foster and promote the formation of crowds. Areas with a greater probability that people will coalesce are identified by open space—sites that can host many people and have a social or cultural association within the city that reinforces the message of the crowd. Using geospatial and statistical analyses that describe those elements, SNoA predicts where people will gather.

Depending on the military context, areas of attraction should be avoided during periods of population unrest. Predicting highly attractive areas for crowd formation is accomplished by locating areas with six general socio-spatial characteristics (Bayat 2010):

- an area large enough to accommodate the demonstrators
- it is easy to get to and from
- it is centrally located near areas of intellectual importance
- it has historic and cultural significance
- flexible space that can be occupied in ways that suit the crowd
- the spaces must be visible to the media and authorities.

The tool combines open spaces with geospatial data from Open Street Map® to indicate areas that contain multiple characteristics. SNoA is intended to alert commanding officers and decision-makers to areas in a city where people are likely to gather given the appropriate social and political conditions. Crowds, particularly protests and riots, can form quickly and the information presented by SNoA predictions should supplement information obtained from field exploration and the engineer's or commanding officer's own knowledge. The tool is not intended to make decisions for engineers or commanding officers, but instead augments other available information. The output is rendered as a heat map.

Running the Tool in ENSITE
In the first pass analytics, the SNoA tool analyzes an urban area's road networks, land use, and population density datasets to rank spaces within a city that are highly connected and are close to where people live. The results rank centrally located open spaces that are accessible to many people and are color-coded red, amber, and green. A red designation marks locations that are highly conducive to gatherings with amber and green designations marking areas decreasing in attractiveness. After the first pass analytics, a more detailed analysis is run based on user-specified selections. Those selections include transportation options such as bus and train stations and stops, taxi stands, and pedestrian path networks; cultural and historic heritage sites; places of power such as government buildings or police and military areas; and intellectually important areas like universities, book stores, cafés, and theaters.

Figure 1 provides example output of the different levels of first pass SNoA analysis as follows A) open space combined with population restrictions; B) sites near modes of transportation; C) sites that are centrally located; D) sites that have socio-cultural significance; E) spaces that have many points of ingress and egress; F) sites that are highly visible to the media and authorities; and G) results from individual analyses can be combined for more accurate predictions based on different socio-cultural contexts.

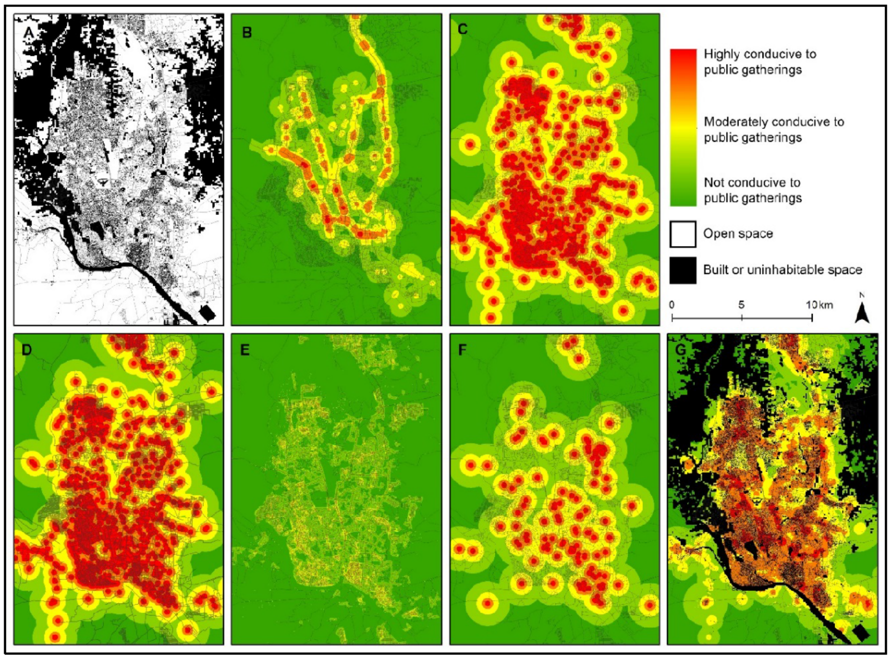

Figure 1. Example results of all SNoA variables (ERDC/CERL 2017).

Metadata

Author/POC: Ellen R. Hartman, Ryan W. Keeling, and Kate A. Morozova

Language: ArcGIS, R

Inputs: OpenStreetMap contributors. (2015) Planet dump [Data file from January 2017]. Retrieved from https://planet.openstreetmap.org.
IUCN and UNEP-WCMC (2016), The World Database on Protected Areas (WDPA) [Online], [January 2017], Cambridge, UK: UNEPWCMC. Available at: www.protectedplanet.net.

Outputs: Heat map of socio-spatial characteristics

References: Bayat, A. (2010). *Life as Politics: How Ordinary People Change the Middle East*. Stanford University Press.
Fay, Kathryn O. and George W. Calfas. "Heritage at Risk: Mapping as a Form of Protection and Preservation for Global Heritage Sites." In NATO Legal Gazette, Issue 38; 2017; In Press.

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14. ABSTRACT

To sustain itself as the world's premier land power, the U.S. Army needs the capability to support expeditionary forces by projecting a minimal basing footprint with reduced logistical burdens. Strategically sited contingency bases (CBs) allow the Army's expeditionary forces to rapidly respond throughout a joint area of operations. To help with this goal, the Army is funding work in the Engineer Site Identification for the Tactical Environment (ENSITE) program, which is dedicated to empowering military planners with the data and knowledge to site CB locations. ENSITE's core-software platform builds upon leading geospatial platforms already in use by the Army and is designed to offer an easy-to-use, customized set of workflows for CB planners. Within this platform are added software components (plug-ins) that add specific and powerful functionality and features for analyses, while minimizing the program's complexity to the end user. This report provides a snapshot of the ENSITE plug-in development process. Completed midway in the four-year ENSITE research effort, this report provides an overview of the initial process of developing 10 plug-ins and reflects on the way forward for the plug-in development process.

15. SUBJECT TERMS
Military bases—Location, Data curation, Geospatial data, Computer programs, Plug-ins (Computer programs), Military planning

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